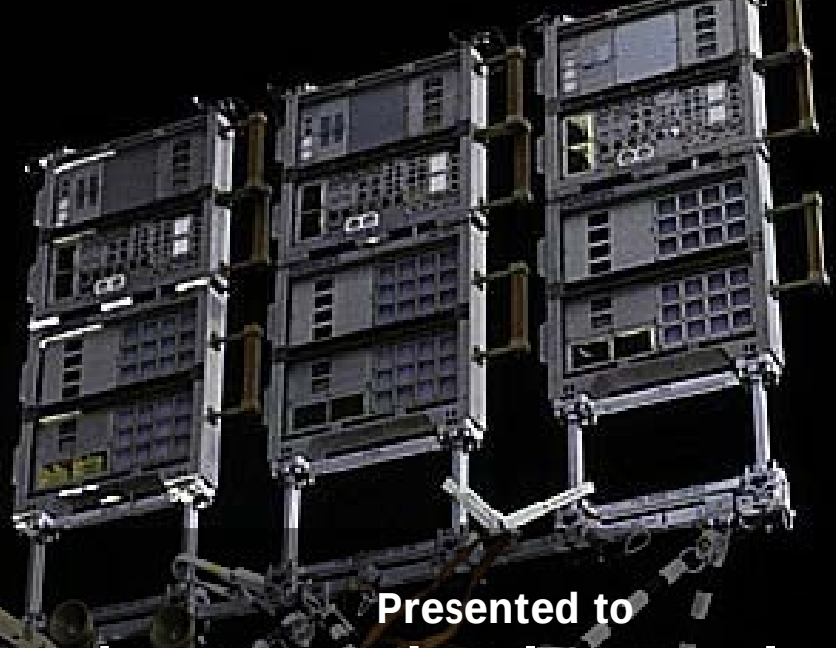
Induced Contamination Predictions for JAXA's MPAC&SEED Devices

Micro PArticle Capturer and Space Environment Exposure Device



Presented to

The International Symposium on "SM/MPAC&SEED Experiment"

March 10-11, 2008

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Boeing – Houston Space Environments Team

Image courtesy of NASA

Acknowledgement

The assistance of Naoko Baba and Kichiro Imagawa (JAXA) in obtaining MPAC&SEED contamination measurements is gratefully acknowledged.

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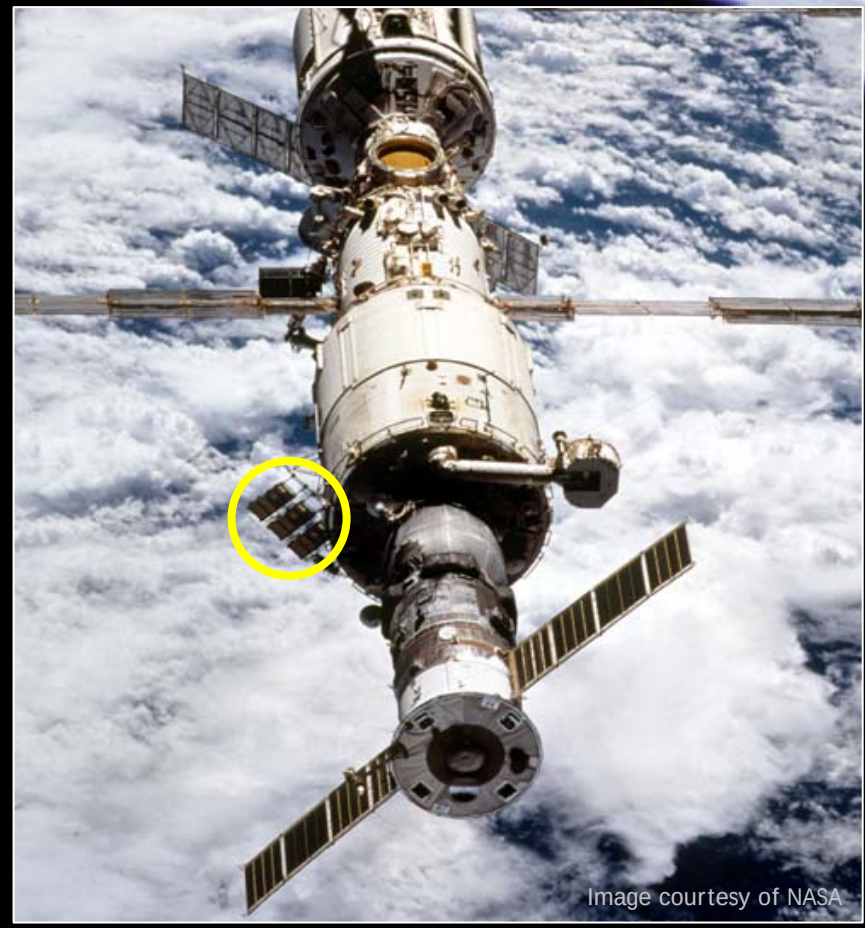
Introduction

SM/MPAC&SEED Experiment deployed on the Service Module port-nadir side
(View from International Space Station Aft end)



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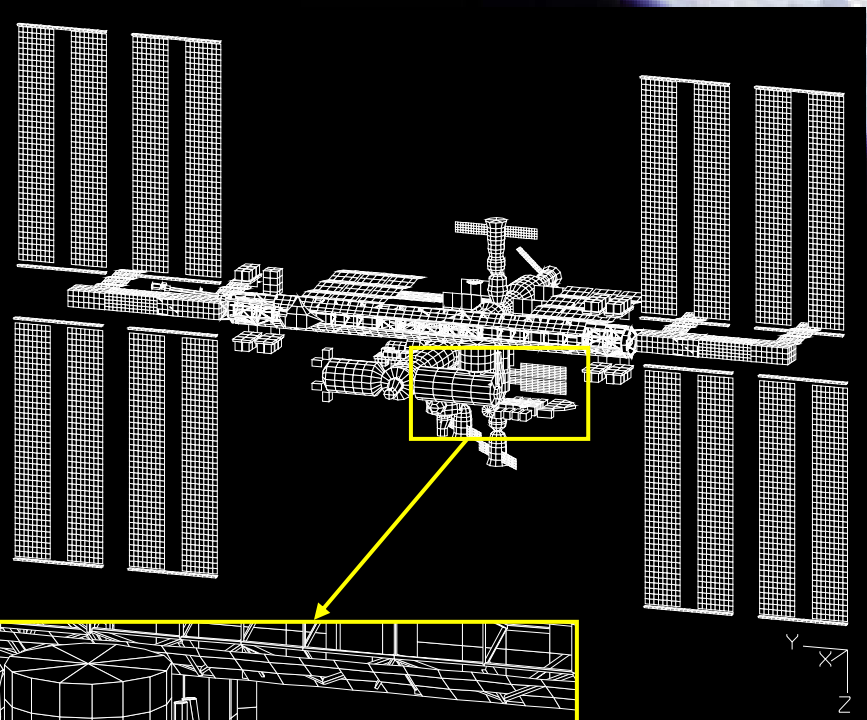
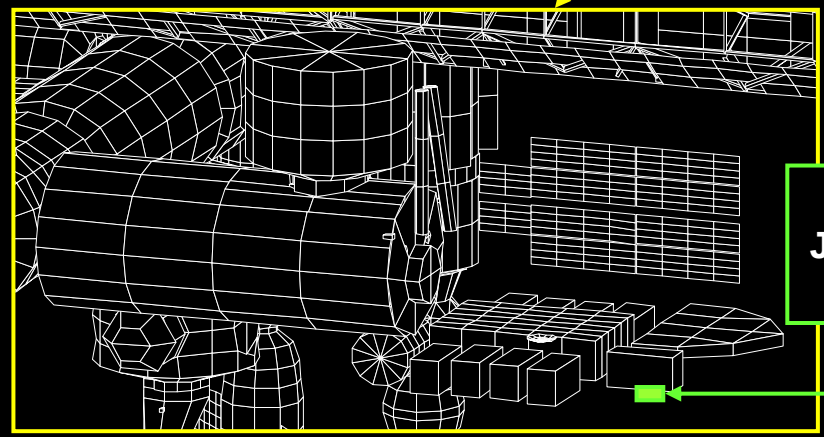
Introduction

SM/MPAC&SEED Experiment deployed on the Service Module port-nadir side
(View from International Space Station Aft end)

JEM/MPAC&SEED Experiment to be deployed on Japanese Experiment Module Payload Site
(Facing in RAM or +X Direction)





Approximate JEM/MPAC&SEED Location

Image courtesy of NASA

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Background – SM/MPAC&SEED

- Three identical SM/MPAC&SEED units.
- Samples on the ram and wake facing surfaces.
  - MPAC – experiment to capture micrometeoroids and space debris particles.
  - SEED - exposure experiment to characterize degradation of materials in LEO.

A single MPAC&SEED Unit (Ram-Facing Surface)

References:
Neish, et. Al. *Microparticle Capture on the International Space Station Using Aerogel and Polyimide Foam*;
Imai, F. and Imagawa, K. *NASDA's Space Environment Exposure Experiment on ISS: First Retrieval of SM/MPAC&SEED*.

Image courtesy of NASA

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Background – SM/MPAC&SEED

- **All 3 units deployed on October 15, 2001**
  - **First unit retrieved on August 26, 2002 -** *315 Days*
  - **Second unit retrieved on February 26, 2004 -** *865 Days*
  - **Third unit retrieved on August 18, 2006 -** *1403 Days*

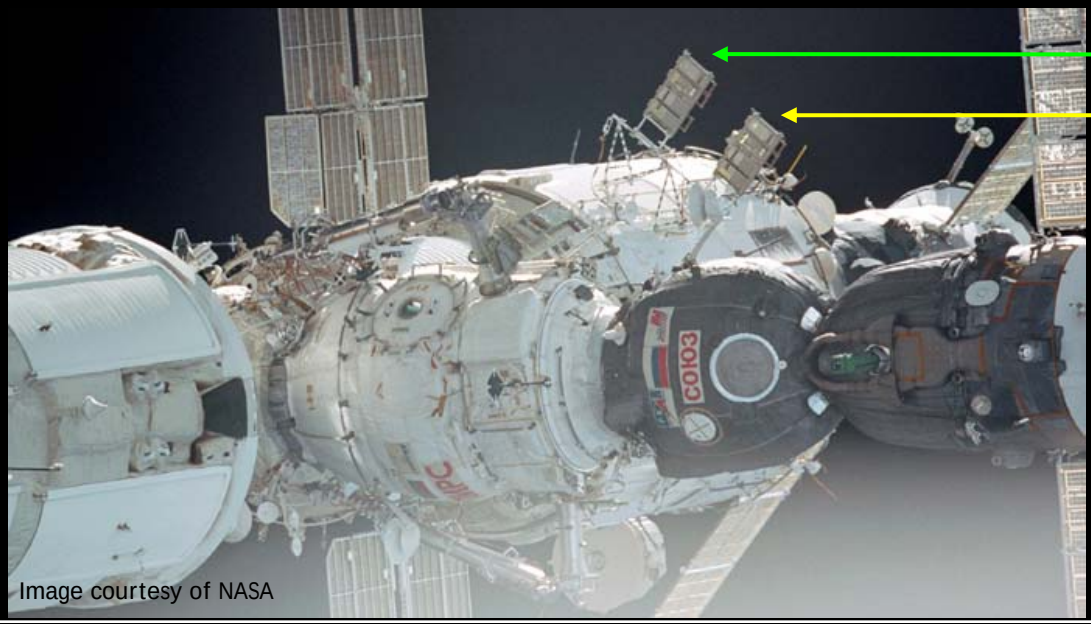

Image courtesy of NASA

MPAC&SEED with Unit 1 Removed
(Unit 2 was relocated into the position previously occupied by Unit 1)

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Background – JEM/MPAC&SEED

- JEM/MPAC&SEED to be launched on ISS Flight 2J/A (ECD March 2009) with SEDA/AP External Payload
  (SEDA/AP: Space Environment Data Acquisition equipment-Attached Payload)
- Samples on the ram facing surface.
- Planned exposure duration of 3 years.

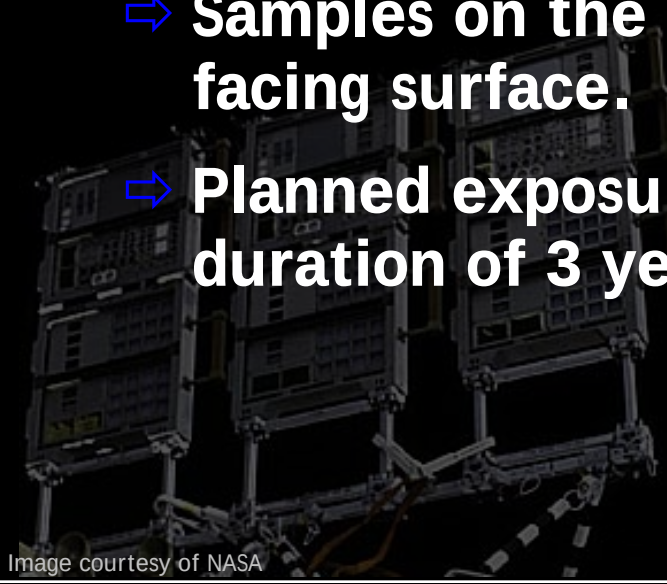
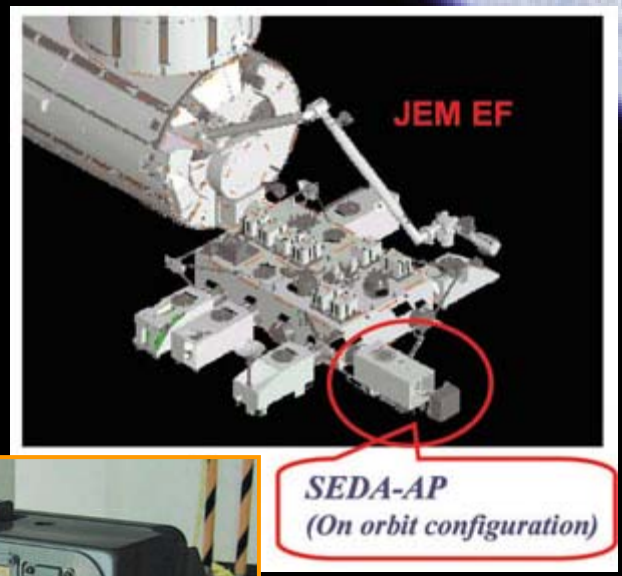


Image courtesy of NASA



JEM/MPAC&SEED

Reference:
JAXA. Space Environment Data Acquisition equipment-Attached Payload (Website), http://kibo.jaxa.jp/en/experiment/ef/seda_ap/, 15 Feb. 08.

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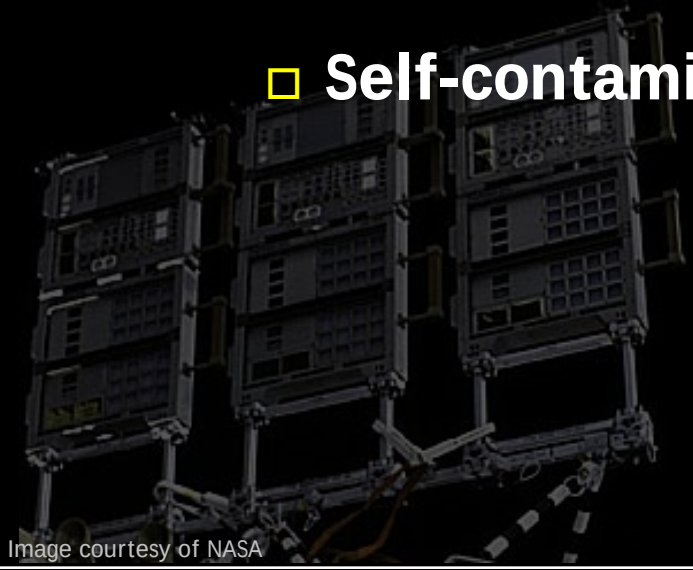
Contamination Sources

- **Possible contamination sources :**
  - **Material outgassing-induced contamination**
  - **Thruster plume-induced contamination**
  - **Propellant purges**
  - **Water vents**
  - **Self-contamination**



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SM/MPAC&SEED

Induced Contamination Predictions and Measurements

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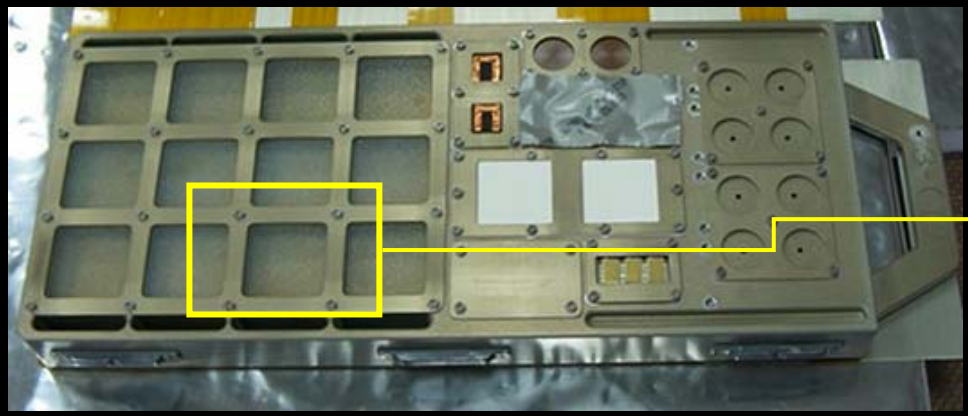
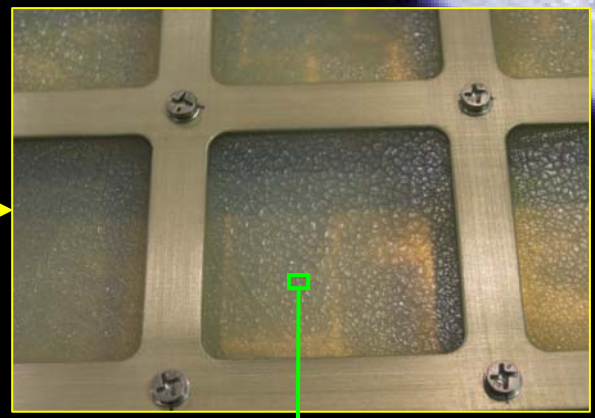
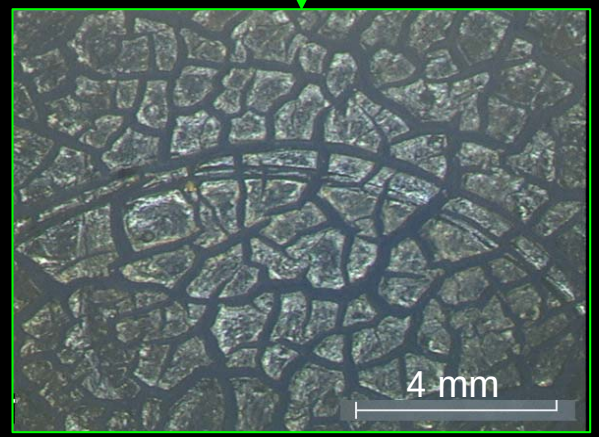
SM/MPAC&SEED Contamination Observations

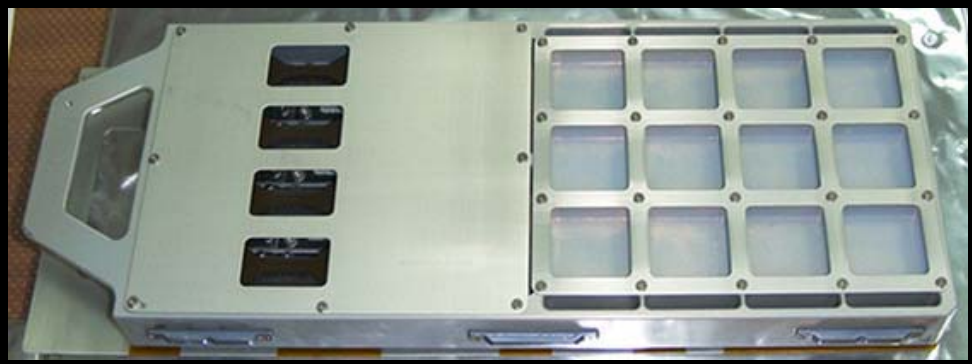


Wake face



Aerogel Sample





Ram face

Reference: Neish, Michael; Imagawa, Kichiro; Inoue, Toshihiko; Ishizawa, Junichiro; Kitazawa, Yukihito; Yamaura, Yukiko; Murakami, Atsushi; Ochi, Yoshiyuki. *Microparticle Capture on the International Space Station Using Aerogel and Polyimide Foam*.

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SM/MPAC&SEED XPS Measurements

- **X-ray Photoelectron Spectroscopy (XPS) used to measure element composition and depth profiles.**
  - **Element composition:**
    - **Silicon major constituent on ram side. Also present on wake side in lesser quantities.**
    - **Other constituents: oxygen, carbon, nitrogen, sodium, iron, and nickel.**
  - **Approximate Contamination Depth based on XPS Measurements:**

Measured Contamination Depth - Angstroms (Å)			
Side	*Unit 1*	*Unit 2*	*Unit 3*
Ram (1)	300	750	930
Ram (2)	300	750	940
Wake (1)	55	100	110
Wake (2)	500	70	85

Reference: Baba, Naoko; Imagawa, Kichiro; Neish, Michael; and Inoue, Toshihiko. *External Contamination Control for JAXA Spacecraft*. ISTS 2004-h-06. Copyright 2004 by the Japan Society for Aeronautical and Space Sciences and ISTS.

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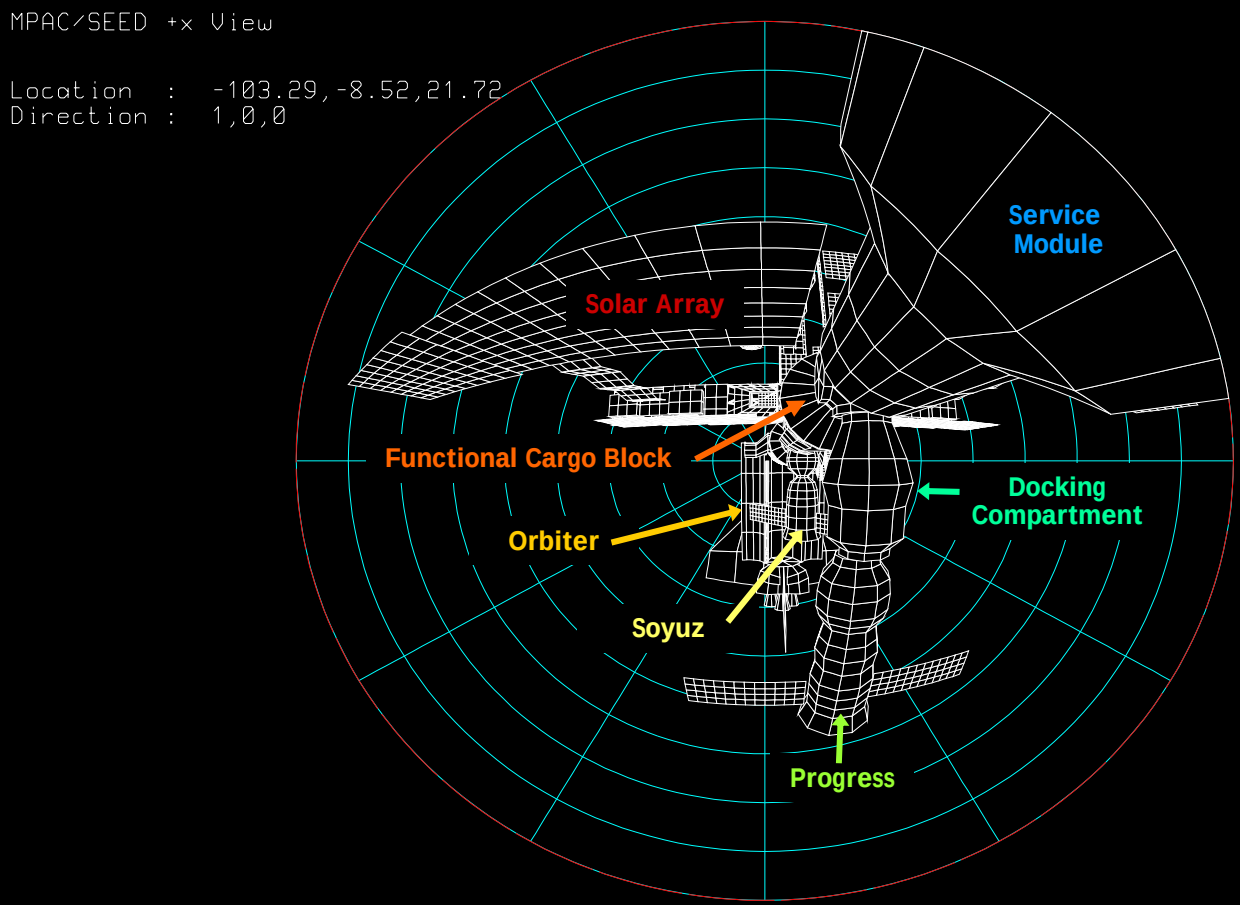
Contamination Sources
Material Outgassing

- **Hemispherical View from SM/MPAC&SEED Ram Side:**



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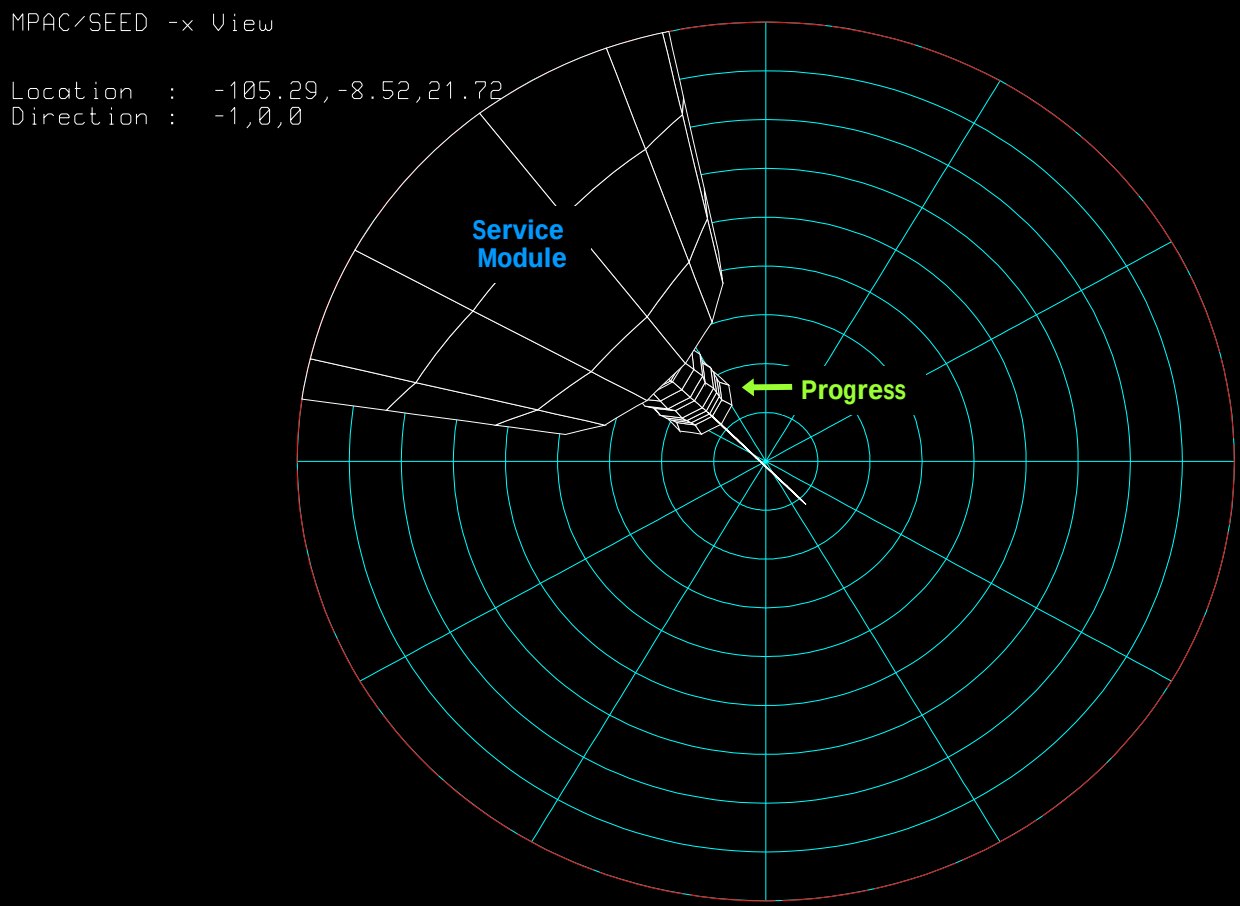
Contamination Sources
Material Outgassing

- **Hemispherical View from SM/MPAC&SEED Wake Side:**



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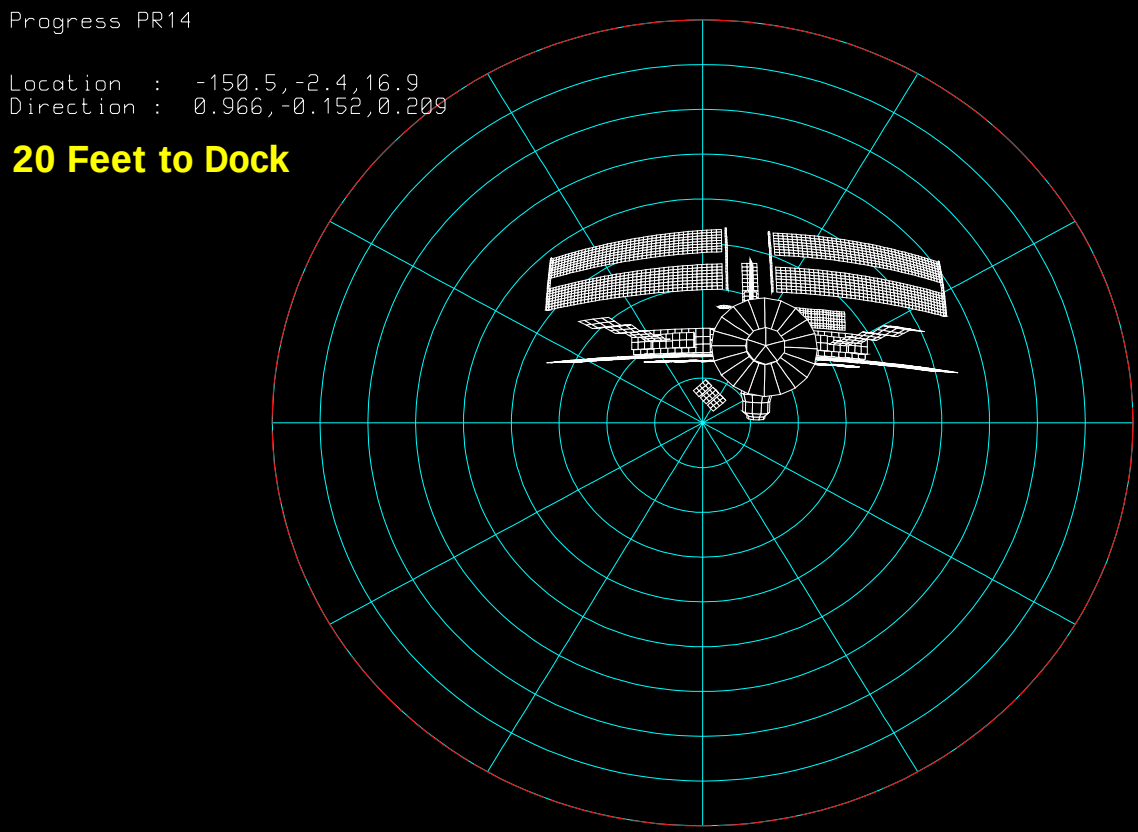
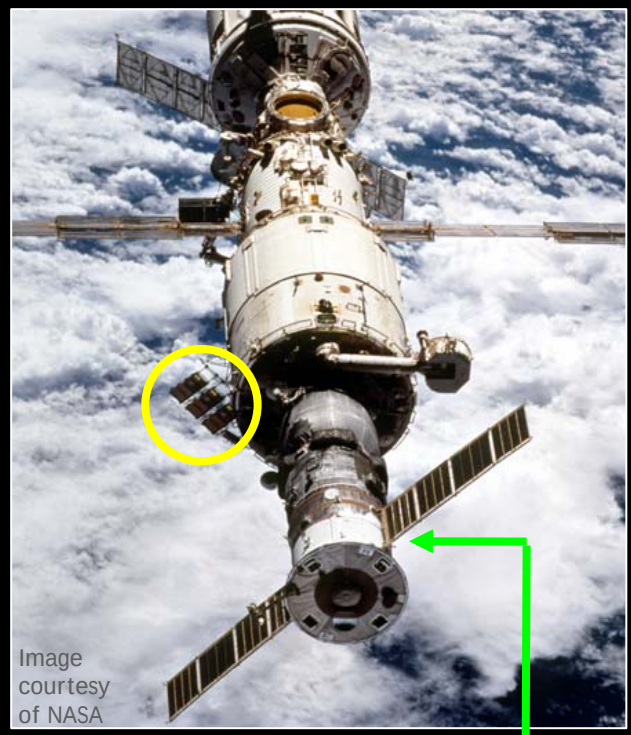
Contamination Sources
Thruster Plume

- **Hemispherical View to SM/MPAC&SEED wake side from Progress braking engines:**





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Contamination Analysis

- **Materials Outgassing Analysis:**
  - Materials lists compiled for each ISS element.
    - Matched to available outgassing rate test data.
    - Other factors include temperature estimates, time decay scaling, and material quantity.
  - Contamination calculated using an analytical model based on physical models of molecular transport.
    - Geometric model, view factor calculation, & transport routines also utilized in calculation.
- **Thruster plume contamination analysis:**
  - Available jet firing data used to simulate thruster firings.
  - Contamination calculated with semi-empirical model based on flight experiment and chamber test data.

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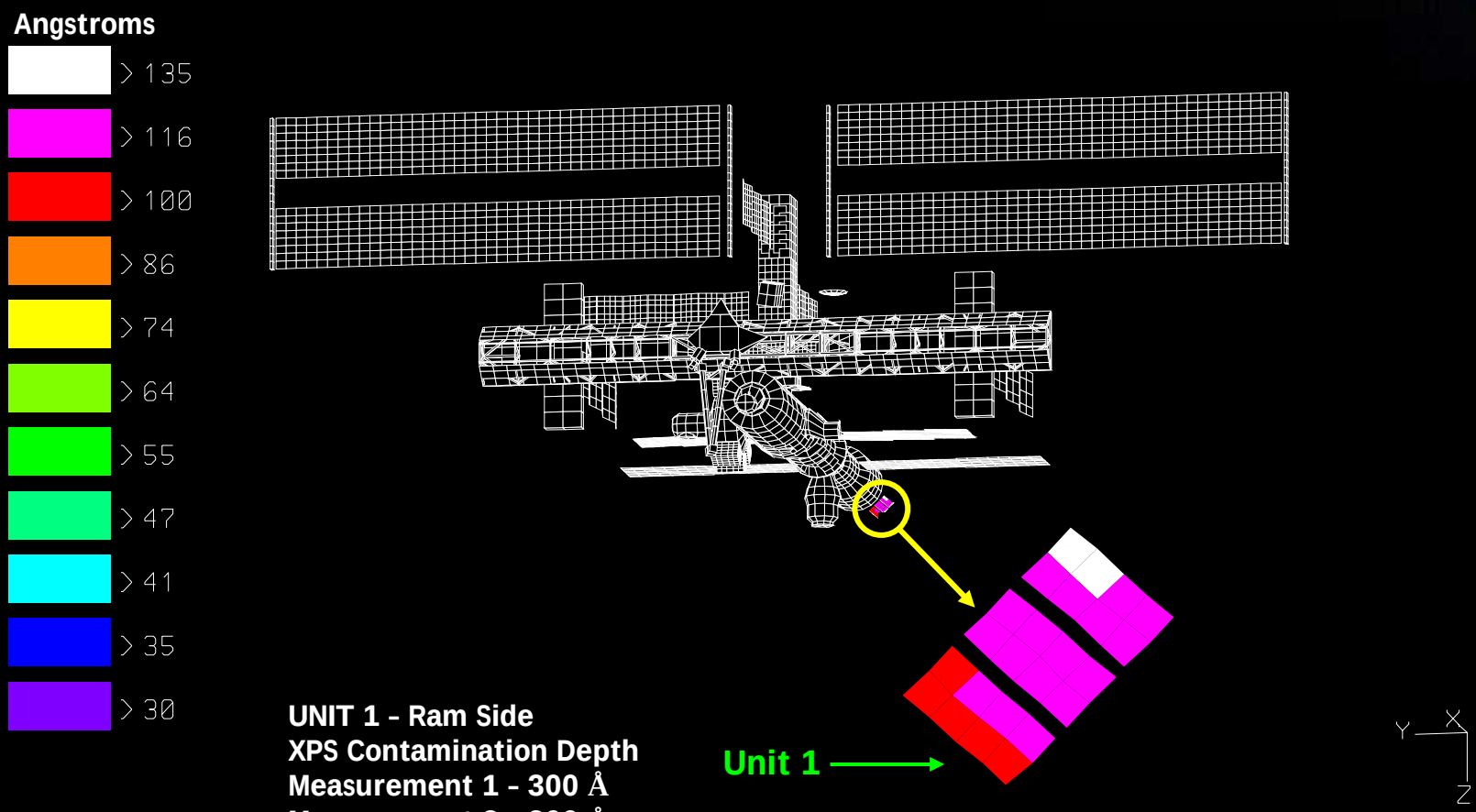
Analysis Results

Example – SM/MPAC&SEED Unit 1 Ram Side (315 Days)



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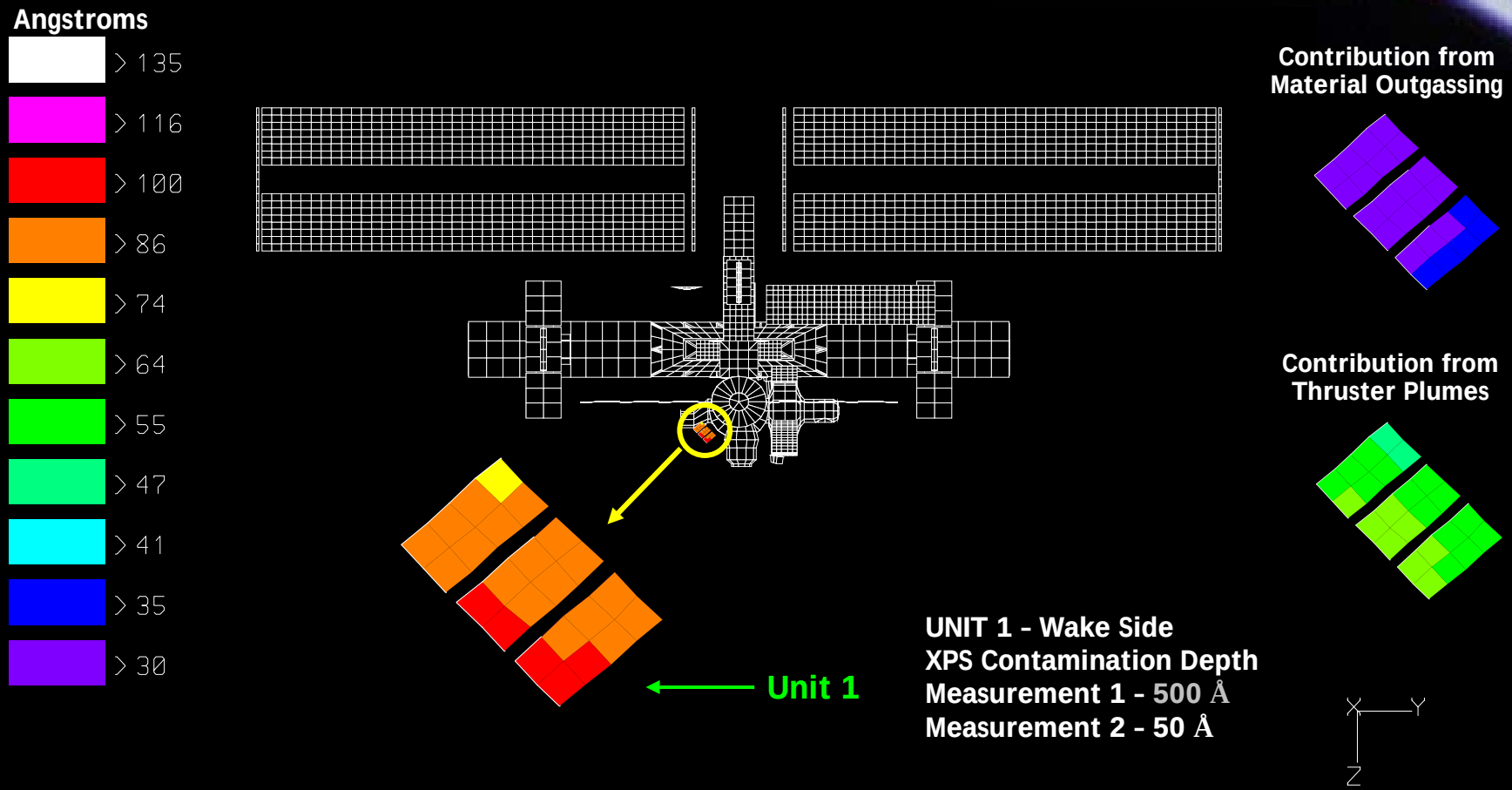
Analysis Results

Example – SM/MPAC&SEED Unit 1 Wake Side (315 Days)



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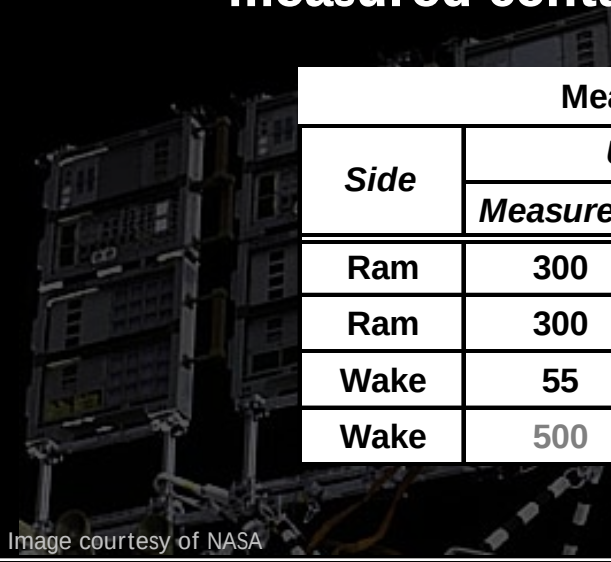
Analysis Summary
SM/MPAC&SEED

- **Results for Ram Side:**
  - Material outgassing induced contamination predicted and measured.
- **Results for Wake Side:**
  - Contamination predicted from combination of materials outgassing and thruster plume impingement.
- **Calculated depth of contamination within a factor of 2-3 of measured contamination.**

Measured Vs. Predicted Contamination Depth (Å)

Side	*Unit 1*		*Unit 2*		*Unit 3*	
	Measured	*Predicted*	*Measured*	*Predicted*	*Measured*	*Predicted*
Ram	300	106 - 135	750	303 - 354	930	459 - 533
Ram	300		750		940	
Wake	55	86 - 103	100	186 - 237	110	317 - 414
Wake	500		70		85	



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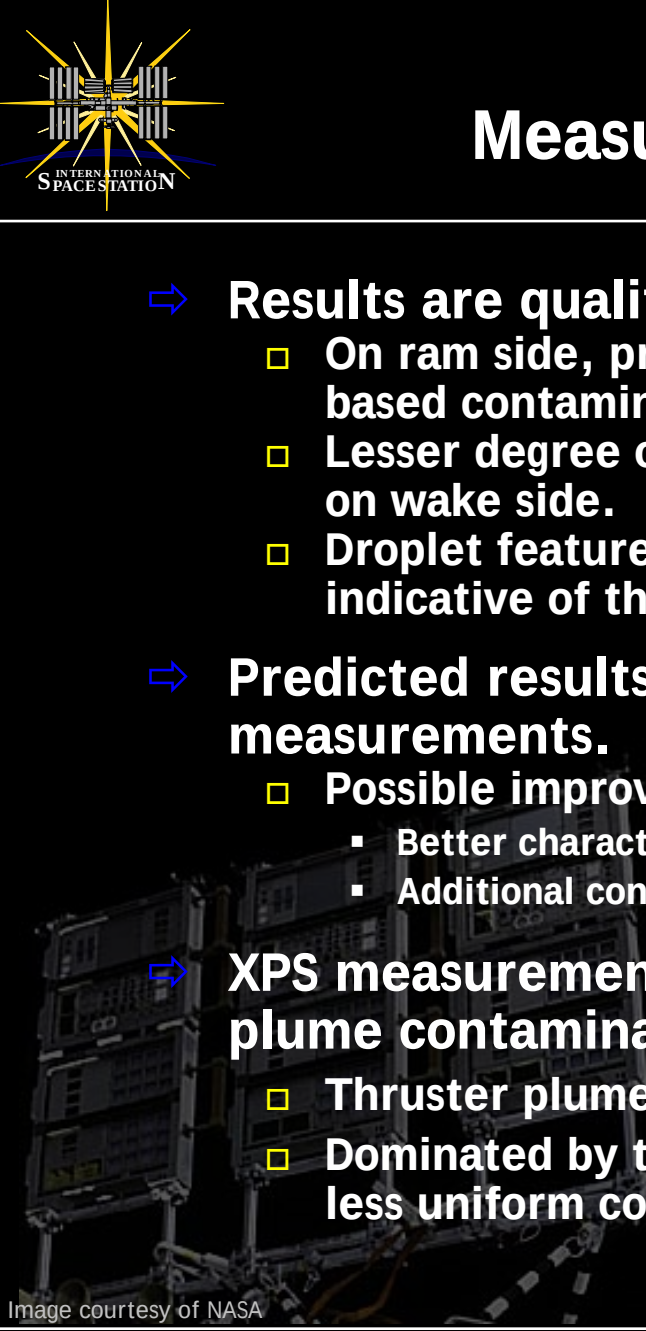
Measurements Vs. Predictions

- **Results are qualitatively consistent with XPS measurements.**
  - On ram side, predictions and measurements dominated by a silicon-based contaminant.
  - Lesser degree of silicon-based contaminant predicted and measured on wake side.
  - Droplet features and presence of Nitrogen on wake side are indicative of thruster plume induced contamination.
- **Predicted results for Ram Side show good agreement with XPS measurements.**
  - Possible improvements for material outgassing calculation:
    - Better characterization of the outgassing sources.
    - Additional consideration for on-orbit thermal environment.
- **XPS measurements have limitations in regard to quantifying plume contamination.**
  - Thruster plumes have multiple byproducts.
  - Dominated by the liquid phase, producing droplet features and a less uniform contamination layer.



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JEM/MPAC&SEED

Induced Contamination Predictions

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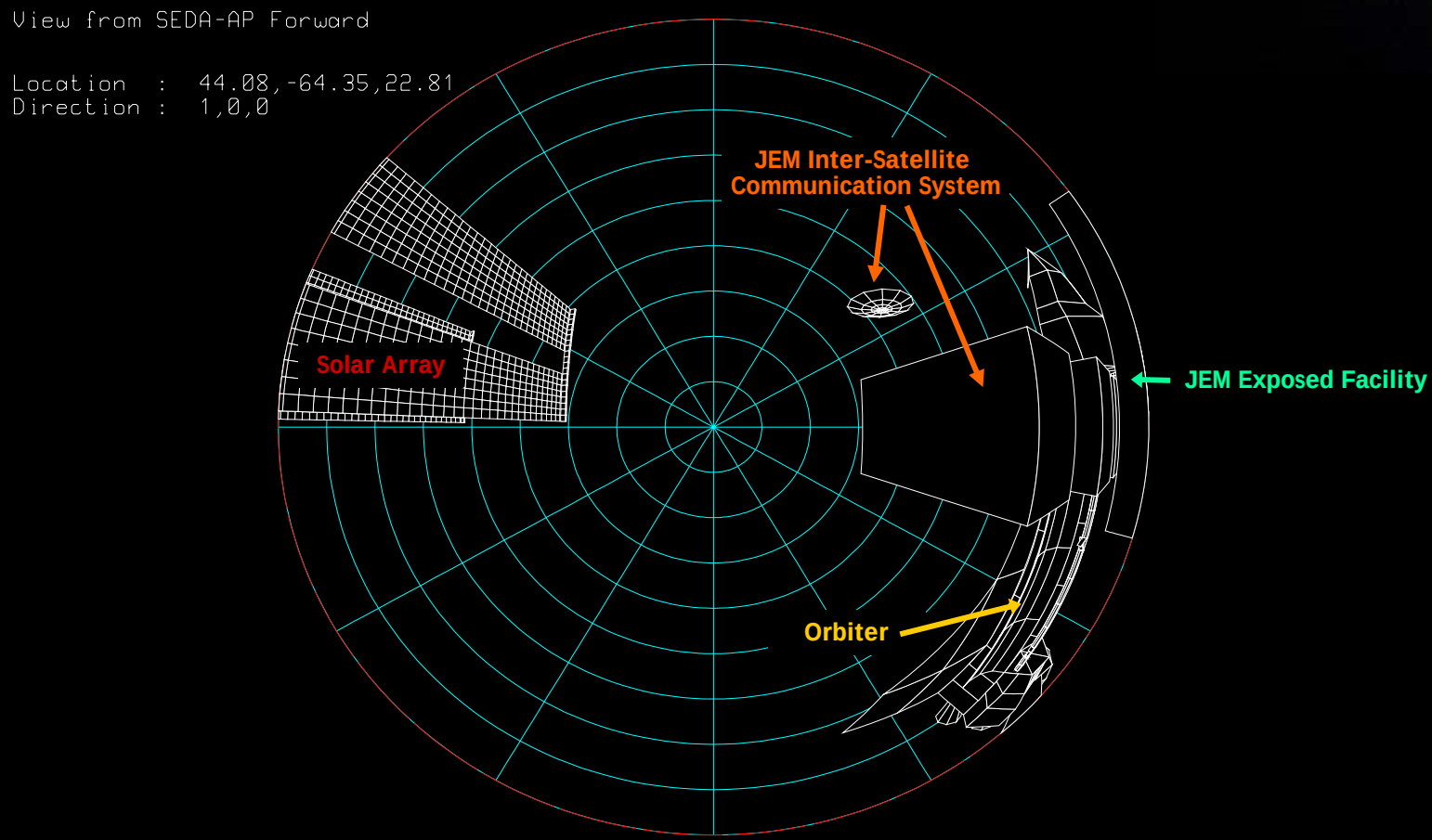
Contamination Sources
Material Outgassing

Hemispherical View from JEM/MPAC&SEED:



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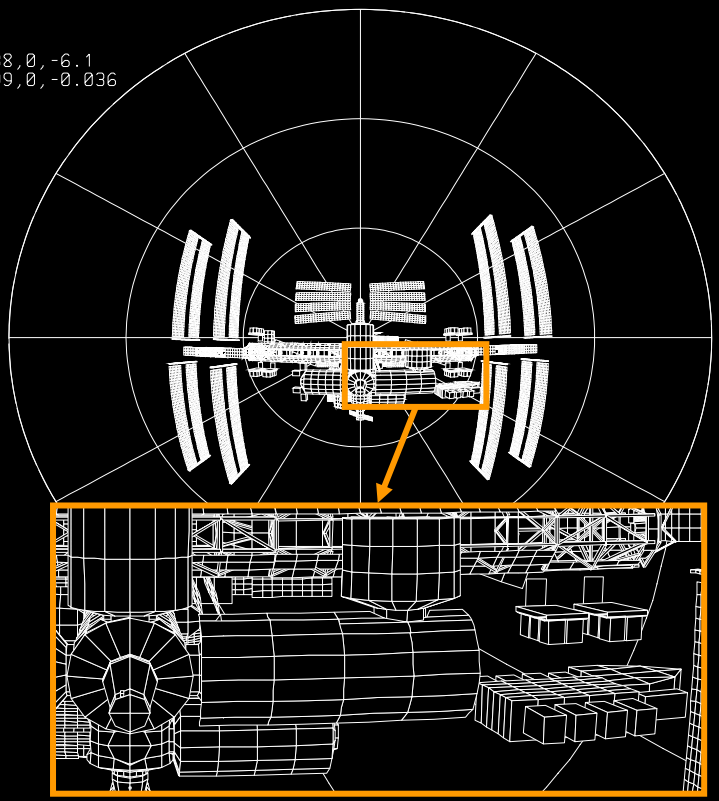
Contamination Sources
Thruster Plume

- **Hemispherical View to JEM/MPAC&SEED from select Orbiter thrusters:**

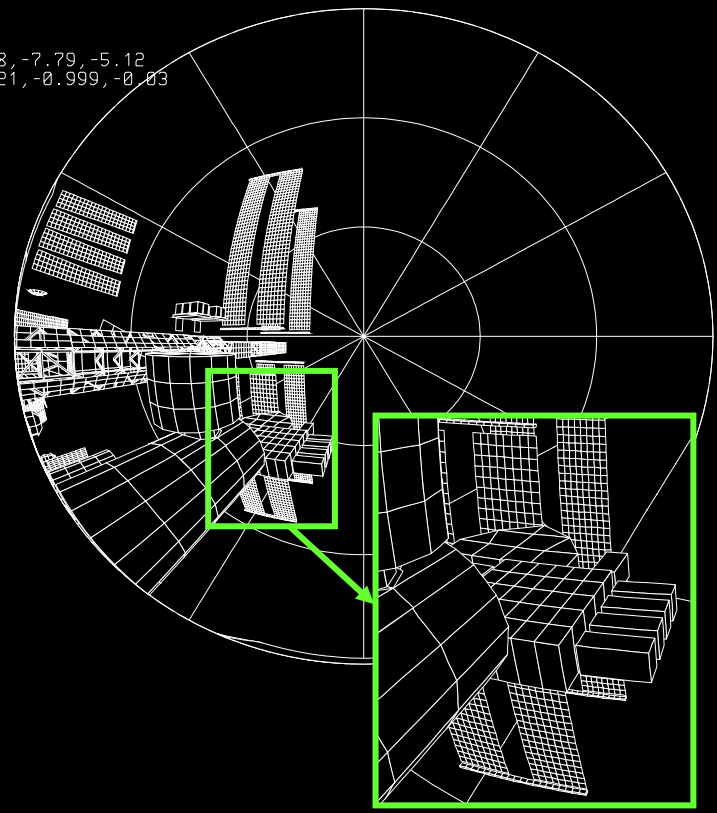
Orbiter Braking Thruster, Range = 100ft

Location : 158.38,0,-6.1
Direction : -0.999,0,-0.036



Orbiter Side Firing Thruster, Mated

Location : 61.78,-7.79,-5.12
Direction : -0.021,-0.999,-0.03



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Analysis Results
JEM/MPAC&SEED

- **Material outgassing is the primary source of induced contamination predicted.**
  - **Depth of contamination layer dependent on JEM/MPAC&SEED surface temperature.**
  - **Majority of outgassing contamination comes from JEM hardware due to close proximity and view factor.**
- **Orbiter thruster plume induced contamination predicted to be negligible.**

Predicted Contamination Depth (Å) due to Material Outgassing Sources (for 3 year exposure duration)

JEM/MPAC&SEED Temperature	JEM (EF and ICS)	ISS (Solar Array & Orbiter)	Total
-40ºC	258.7 Å	3.3 Å	262 Å
-10ºC	100.2 Å	3.3 Å	103 Å
25ºC	41.5 Å	2.9 Å	44 Å

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Conclusions

- Externally mounted ISS payloads are exposed to the induced ISS environment, including material outgassing and thruster plume contamination
- The Boeing Space Environments Team developed analytical and semi-empirical models to predict material outgassing and thruster plume induced contamination.
- JAXA's SM/MPAC&SEED experiment provides an unique opportunity to compare induced contamination predications with measurements.
  - Analysis results are qualitatively consistent with XPS measurements.
  - Calculated depth of contamination within a factor of 2-3 of measured contamination.
  - Represents extremely good agreement, especially considering long duration of experiment and number of outgassing sources.
  - Despite XPS limitations in quantifying plume contamination, the measured and predicted results are of similar scale for the wake-facing surfaces.
- JAXA's JEM/MPAC&SEED experiment will also be exposed to induced contamination due to JEM and ISS hardware.
  - Predicted material outgassing induced contamination to JEM/MPAC&SEED ranges from 44Å to 262Å (depending on surface temperature) for a 3 year exposure duration.

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